AFWL-TR-72-18

AFWL-TR-
72-18

HARDNESS, MOBILITY, DISPERSION, REDUNDANCY AND MISSION EFFECTIVENESS UNDER NUCLEAR ATTACK

H. L. Brode

H. F. Cooper, Jr.

G. G. Leigh

TECHNICAL REPORT NO. AFWL-TR-72-18

May 1972

AIR FORCE WEAPONS LABORATORY
Air Force Systems Command
Kirtland Air Force Base
New Mexico

Approved for public release; distribution unlimited.

38

AFWL-TR-72-18

AIR FORCE WEAPONS LABORATORY
Air Force Systems Command
Kirtland Air Force Base
New Mexico 87117

UNCLASSIFIED

Security Classification

DOCUMENT CONTROL DATA - R & D

(Security classification of title, body of abstract and indexing annotation must be entered when the overall report is classified)

1. ORIGINATING ACTIVITY (Corporate author) Air Force Weapons Laboratory (DEV) Kirtland Air Force Base, New Mexico 87117	2a. REPORT SECURITY CLASSIFICATION UNCLASSIFIED 2b. GROUP

3. REPORT TITLE

HARDNESS, MOBILITY, DISPERSION, REDUNDANCY AND MISSION EFFECTIVENESS UNDER NUCLEAR ATTACK

4. DESCRIPTIVE NOTES (Type of report and inclusive dates)

June 1971-August 1971

5. AUTHOR(S) (First name, middle initial, last name)

H. L. Brode; H. F. Cooper, Jr.; G. G. Leigh

6. REPORT DATE	7a. TOTAL NO. OF PAGES	7b. NO. OF REFS
May 1972	36	None

8a. CONTRACT OR GRANT NO.	9a. ORIGINATOR'S REPORT NUMBER(S)
b. PROJECT NO. 5710	AFWL-TR-72-18
c.	9b. OTHER REPORT NO(S) (Any other numbers that may be assigned this report)
d.	

10. DISTRIBUTION STATEMENT

Approved for public release; distribution unlimited.

11. SUPPLEMENTARY NOTES	12. SPONSORING MILITARY ACTIVITY
	AFWL (DEV) Kirtland AFB, NM 87117

13. ABSTRACT

(Distribution Limitation Statement A)

A review of several war headquarter concepts and missile basing schemes illustrates the diversity of possible configurations to achieve survivable systems under nuclear attack conditions. Each has elements of hardness and dispersion. Some rely on mobility or redundancy and others seek protection through deception. All must be designed to survive the nuclear effects of both large and small yield attack under various scenarios because threat-weapon size, numbers, delivery accuracy and target selection are beyond the control of the defenders. Thus, understanding nuclear effects often is a dominating influence in assessing weapon system effects under possible wartime environments. The lack of such understanding and the resulting uncertainties in assessing survivability under wartime conditions have often led to the demise of otherwise promising and cost-effective systems. (U)

Details of illustrations in this document may be better studied on microfiche

DD FORM 1 NOV 65 1473

UNCLASSIFIED

Security Classification

UNCLASSIFIED

Security Classification

14. KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
Nuclear weapons effects						
Blast and shock						
Airblast						
Ground shock						
Ground motions						
Finite difference methods						

1b

UNCLASSIFIED

Security Classification

HARDNESS, MOBILITY, DISPERSION, REDUNDANCY AND MISSION EFFECTIVENESS UNDER NUCLEAR ATTACK

H. L. Brode
H. F. Cooper, Jr.
G. G. Leigh

TECHNICAL REPORT NO. AFWL-TR-72-18

1C

FOREWORD

This research was performed under Program Element 61102H, Project 5710.

Inclusive dates of research were June 1971 through August 1971. The report was submitted 19 January 1972 by the Air Force Weapons Laboratory Project Officer, Dr. Henry F. Cooper, Jr. (DEV).

This report is an edited version of a paper presented on 15 September 1971 at a NATO Defense Research Group Seminar in Bodo, Norway, by Dr. Henry F. Cooper, Jr., and Major Gerald G. Leigh of the Air Force Weapons Laboratory, Kirtland AFB, New Mexico, and Dr. Harold L. Brode of Research and Development Associates, Santa Monica, California.

This technical report has been reviewed and is approved.

Henry F. Cooper, Jr.

HENRY F. COOPER, JR.
Project Officer

Gerald G. Leigh

GERALD G. LEIGH
Major, USAF
Chief, Facilities Survivability Branch

William B. Liddicoet

WILLIAM B. LIDDICOET
Colonel, USAF
Chief, Civil Engineering Research Division

ABSTRACT

(Distribution Limitation Statement A)

A review of several war headquarter concepts and missile basing schemes illustrates the diversity of possible configurations to achieve survivable systems under nuclear attack conditions. Each has elements of hardness and dispersion. Some rely on mobility or redundancy and others seek protection through deception. All must be designed to survive the nuclear effects of both large and small yield attack under various scenarios because threat-weapon size, numbers, delivery accuracy, and target selection are beyond the control of the defenders. Thus, understanding nuclear effects often is a dominating influence in assessing weapon system effects under possible wartime environments. The lack of such understanding and the resulting uncertainties in assessing survivability under wartime conditions have often led to the demise of otherwise promising and cost-effective systems.

CONTENTS

ILLUSTRATIONS

SECTION I

INTRODUCTION

In the past 20 years a great deal has been learned about the effects of nuclear explosions on military systems. This information has been critical in shaping the very nature of most strategic systems, and yet our understanding of weapons effects is never complete. Early missile silo designs met blast plus nuclear and thermal radiation threats on the basis of rather incomplete research and test knowledge, but the designers used all that was available at that time. Since then nuclear effects protection has been extended to nearly all strategic systems in all their operational modes, making full use of the growing knowledge of weapons effects. But the process is open-ended; as concepts for new weapon systems arise, new aspects of weapons effects become important. When antimissile missiles were first considered, the exoatmospheric effects of X rays and nuclear radiation became a subject for more intensive study. Airblast, ground shock, and thermal radiation have influenced many military systems from the outset, and yet some aspects are still poorly understood; however, periodically one or more of these becomes vital again. Electromagnetic signals generated by nuclear burst are still being studied and their effects taken into account for old and new systems.

As we develop greater protection and require more exacting performance in weapon systems, we create or uncover new sensitivities to nuclear effects. Design for overpressures as high or higher than 7 atmospheres means surviving inside fireballs. Sophisticated electronics with solid-state circuitry and digital computers tend to be more sensitive to electromagnetic pulse (EMP) and transient radiation effects on electronics (TREES). Such logic and control circuitry improves weapon system performance, but may also make the system more

vulnerable. Building missile warheads to survive nuclear attack while reentering the atmosphere at high speed sometimes means going beyond the state of knowledge of heat and shock resistant materials, and each new material or configuration needs fresh examination for its influence on nuclear survivability. Progress in almost any phase of strategic systems leads eventually to a reevaluation of the effects of nuclear weapons and the adequacy of protection.

In the following review of basing concepts, balanced hardening will refer to the physical vulnerability of a system in its "buttoned-up" or "turtle" mode, and will not include its dynamic response or its operational viability in a mission performance sense. In other words, we will examine protection for missiles before launch and war headquarters without message exchanges.

Throughout this review one feature will stand out: the dominance of weapons effects. Nuclear survival is always of first priority, while cost and operational convenience or even reliability are secondary.

The review is divided into two basic types of facility: (1) the one-of-a-kind center such as a war headquarters and (2) a large number of similar installations such as missile silos. Clearly, a single installation presents an entirely different challenge to an enemy attack planner than does a large number of missile silos or other targets, and the defenders must take an equally different view of the adequacy of protection.

SECTION II

WAR HEADQUARTERS CONCEPTS

1. DEEP UNDERGROUND CENTER

a. Features

A compact facility buried 1 or 2 kilometers below the surface and capable of closing all openings to the outside during attack can survive a direct hit of tens to hundreds of megatons. While damage may be likely from the heaviest of attacks, an enemy could not be sure of destruction and might find less motivation for any attack at all. Incoming and outgoing messages may continue to be transmitted through multiple and redundant hard channels that lead eventually to land lines or radio links with other commands. Power and heat dissipation must be provided internally and independent of outside sources or sinks if vulnerabilities are to be minimized.

b. Problems

The only weapon effects that can damage such a deep facility are ground motions, some electromagnetic signals, and perhaps some blast waves down ducts and tunnels. Even so, it is not clear how much of the explosive energy from a very large burst gets coupled into the ground initially nor how strong the ground shock may be after traversing thousands of meters of rock and soil; nor is it well understood how best to protect an underground facility from such motions, although a great deal of research has been directed to these issues. A primary concern will be for the preservation of long tunnels or connections across major faults or fissures in the surrounding geology. Adequate EMP protection is in many ways easiest in this configuration, and blast closures are quite feasible at all levels. In spite of lingering uncertainties about some

effects, the deeply buried center has good prospects for survival and need not have high operating costs. Continued operation after attack depends on the nature and extent of communications provided, but can be made equally probable.

2. DEEP UNDERGROUND COMPLEX

a. Features

A set of facilities connected by tunnels which can either perform portions of the war headquarters mission or, better, which can each act as a junction for semimobile command and communications offers dispersion as well as hardness. A few extra kilometers of tunnel could defocus an aim point into an ill-defined area and therefore make high accuracy in weapon delivery not a great advantage. A dispersed headquarters could operate via closed-circuit TV and other electronic links and accomodate a truly mobile command and message center. The dispersed functions make heat dissipation, redundant communications links, and some aspects of life support easier to provide.

b. Problems

This deep underground concept (deeper than a kilometer) suffers from all of the problems of the single fixed deep center (ground shock, blast, and EMP), but is even more affected by the likely large motions at major faults and strata. Such displacements are likely to interrupt tunnel systems at many places. The propagation of blast in tunnels is also of greater concern where greater reliance is placed on keeping tunnels open. However, the probability that any single burst would destroy the functions of such a complex is much less than for the single center.

c. Variants

Tunnel systems at shallower depth but still in competent rock--perhaps at only 100-meter depths--could be cheaper to construct and therefore could afford more kilometers of tunnel. Such shallow tunnel systems could dissipate heat easier, could more easily provide multiple external connections for

reliable communications and access, but would provide less assured protection per mile of tunnel. Tunnels created just below the surface by "cut and cover" construction would be cheapest to construct in many areas, but would offer the least protection and could invite attack on each of the junctions or alternate centers. A further alternative is to provide for continuous operation of the headquarters while moving in tunnels, thus providing no logical aim points. But the miles of tunnel and the protected communications cabling thus made necessary along with the added operational complication would make such a "dispersed" headquarters very expensive. Large cable loops, of course, are subject to high current surges induced by the EMP.

3. BARGE-BASED HEADQUARTERS

a. Features

In areas with extensive inland or protected waterways, particularly in such areas with considerable barge traffic, a floating headquarters may prove feasible. A vessel of appropriate shallow draft but with essential structures below the water line and with dispensable superstructure above the water could be made quite hard. If built to resemble a commercial barge and operated so as to mingle with the usual traffic, it might also avoid easy detection and make sabotage or interferrence less likely or easy. Such a hard mobile (10 to 30 atmospheres and several knots) center would need several communications alternatives for normal and wartime operation. It could operate in a largely covert fashion and, if discovered and attacked, could enjoy impressive protection from blast, water shock, thermal radiation, fallout, and debris impact.

b. Problems

While nearly all effects are well countered in a shallowly submerged hull, the protection against EMP and water waves should be carefully considered and the exposure to possible sabotage studied. If covert operation is taken seriously, then crew changes and communications problems may prove difficult to

solve. Unlike so many systems which depend on covert or deceptive operation, however, the hard barge is not immediately dead in the water when its identity and location become known. When discovered and attacked, the hard barge is not easily destroyed.

4. EMERGENCY AIRBORNE HEADQUARTERS

a. Features

A compact and austere version of a war headquarters could be accommodated in a large transport aircraft. In times of emergency such a plane could operate at low altitudes or over areas secure from enemy radar or other search and could communicate, at least periodically, with military bases or communications relay points (via UHF, modulated lasers, or other secure transmission).

b. Problems

While a great many problems would confront such a center, the most serious stem from the need for avoiding detection in large operating areas (since an airplane is not very hard) and the possible importance of long endurance (not a notable feature of aircraft).

5. LAND-MOBILE CENTERS

a. Features

A great many variations of land mobile schemes have been suggested, ranging from railroad trains to off-road vehicles and hovercraft. Trains and trucks disguised to look like commercial vehicles have frequently been suggested as being able to "get lost" in the general traffic. Since such special trains and trucks are not easily hidden in this way from a sophisticated enemy and since such public exposure would make sabotage and disruption easier, many such concepts have grown away from deception by disguise and moved to unpopulated and often undeveloped areas to travel about on private roads or overland avoiding all roads. In some cases a command center has been proposed to operate indistinguishably among similar military vehicles, such as mobile launcher/

carriers. Without disguise, such vehicles (trains, trucks, off-road transporters, or hovercraft) must be protected from observation. Being inherently soft (unable to withstand more than about 1 atmosphere blast pressure), they need large areas in which to "get lost" and high speeds to counter periodic observations by enemy aircraft, satellites, or ground observers.

b. Variants

Any number of variants have been explored, but a most promising one improves the hardness, reduces the dependence on deception, and cuts down on the operating costs and inconveniences attendant with continuous mobility. The concept requires a covered revetment or hardened garage, a railroad or highway tunnel, or a mine drift every few kilometers. The mobile headquarters races periodically from one to another of these shelters under cover of darkness, fog, smoke, or the movement of similar dummy vehicles, and once under shelter connects to secure land line redundant communications links.

c. Problems

Limited hardness and limited area for operation are critical for mobile systems, but preventing an enemy from locating the center is the biggest problem. Special effort is needed to make a train, a truck, or an off-road vehicle withstand as much as 1 atmosphere overpressure, and no designs so far prevent sliding and rolling over at overpressures above 1.5 atmospheres. The peak wind pressure at 1.7 atmospheres peak overpressure is 0.8 atmospheres, which is enough to cause lateral accelerations several times that of gravity for most vehicles. The best solution is to spend most of the time in revetments (least expensive), in hardened garages or tunnels, or to travel on sunken or covered roads. There is an obvious trade-off between operating area (and speed) and hardness or degree of protection. An extremely hard vehicle needs little speed and only modest areas in which to move to avoid destruction in an area barrage attack. The ultimate in hardness comes with the underground tunnel system

(discussed earlier), but that concept requires expensive excavations and makes communications difficult. A soft vehicle must be very fast and have very large areas in which to run and still must hope to avoid detection and tracking by an enemy. Except in the vastness of Siberia or Western America, it is not obvious that there is enough open space to accommodate an unhardened mobile center and to keep area saturation bombing from being a preferred attack mode for an enemy. The garages or revetments spaced appropriately in the operating area can be a reasonable compromise. The hardness of garages or revetments dramatically shrinks the required area and reduces the importance of speed. If all the equipment is on the mobile center, then the shelters can be kept inexpensive and thus not too costly to replicate. At the heart of any such system, however, is the prevention of an enemy from precisely locating the center. Even the deep underground concepts are not immune to seismic detection or electronic sensing. Any surface mobile system would appear to need active deception and obscuration for protection. Frequent changes and improvements would need to be considered, and special noismaking, jamming, and decoy deployment should be a part of planning for crisis operations.

6. UNDERWATER CENTERS

a. Features

A fixed underwater center--even one in the protected waters of a bay or lake--has some inherent hardness not available to the aboveground center and may be less easily located, but is far too vulnerable to justify any appreciable costs or increased inconvenience or unreliability in operations. However, the underwater barge which spends most of its time parked in shallow water, moving frequently, paying out communication cable as it goes, could be quite hard and not fixed.

b. Problems

Protection from water shock from underwater nuclear bursts is required but is minimized by operation in shallow water since water shocks do not propagate far in shallow water and relief of shock pressures on the hull is faster at shallow depths. But shallow water brings the possibility of water wave action. A free-floating submarine is more vulnerable than a bottom crawler or a buoyant underwater center which parks on the bottom most of the time. Provision for alternate communication via remote buoys and whip or floating antennas would be prudent. Operation in closed or controlled waters such as lakes and inland waterways would make enemy detection or location less likely and enemy attack more difficult.

SECTION III

MISSILE BASING CONCEPTS

1. FIXED LAND-BASED MISSILES

a. Features

Both Soviet and US missiles are now based in large numbers in below-ground silos. Early missiles required elevation to ground level before launch, but current versions allow hot launches from the stored position in the silos. Cold launches, as with the Polaris, are also possible and could reduce silo diameters for greater hardness. Silos in soil or poor rock are subject to appreciable ground motions at the higher levels of protection. Basing in hard rock can minimize the motions, but may subject the silo to very nonuniform loads and high accelerations. Damaging impacts from crater-ejected rocks is also a greater hazard in hard rock silos. Superhard silos with survival expected to extend to the level of 200 atmospheres have been proposed for basing in a variety of geologies. The designs tend to reflect the influence of the local site on the weapons effects. In soils greater rattle space must be provided to accommodate larger expected ground motions. One such scheme, good for rock as well as soil, surrounds the silo with a pool of water to isolate the silo and missile from the high shears and rock motions in the surrounding geology. At the high levels of protection the thickness of silo lids is generally dictated by nuclear radiation shielding requirements rather than structural strength. Moving massive doors requires large stores of power and heavy linkage, unless the mass required for shielding is a fluid that can be drained away before opening the shell. A thick layer of sand or gravel over a silo has been proposed as an effective way to upgrade a silo's survivability, providing the sand or gravel can be dumped properly before launch.

b. Problems

The biggest problem for fixed land-based missiles is that they are fixed, thus incapable of continuing indefinitely to counter increases in enemy accuracy (decreasing circular error probable (CEP)) with corresponding increases in silo hardness. When the CEP becomes less than the kill radius even for a small-yield weapon, there is little to be gained by adding more expensive silos. When the miss distance goes to zero (i.e., when the enemy never misses), survival can still be bought by becoming superhard, which means going deeper underground and providing multiple or repairable exits. Such deep underground missile storage leads to another type of basing, however, since infinite hardness is not achievable but is the necessary response to zero CEP on fixed bases. As CEPs shrink, hard silos become less attractive.

2. LANDMOBILE

a. Features

All of the suggested variations of landmobile centers mentioned for war headquarters are available for missile basing (railroad cars, highway trucks, off-road vehicles, and even hovercraft). The rules are different, however, since the redundance of large numbers makes each moving vehicle a less valuable target.

b. Problems

The existence of many missile-launching trucks or trains is not likely to be acceptable on public roads or in populated areas except in time of national emergency. Excluding all such public areas would seriously restrict available operating areas and would make most existing rails and roads unusable. Off-road missile carriers could reduce the public exposure by staying in uninhabited areas, but the limits on terrain, on ecological impact, vehicle speed, and hardness do not allow a mobile system of very many missiles, at least not in the United States or Europe. Few landscapes are hardy enough to withstand

the frequent traversal of off-road vehicles. Special (nonpublic) roadways would need to be improved and maintained making the system more costly and less flexible. The same problems exist here with moving vehicles in getting them to stand up to the blast winds. They are just not hardenable on land--particularly the hovercraft. Nearly all continuously moving systems require additional manpower (not essential to launch) for driving, for guard duty, for vehicle maintenance and repair, for road or rail maintenance and repair, for security, and for added communication and traffic control.

3. CANAL BASED (LANDMOBILE)

a. Features

One landmobile system with appreciable hardness (perhaps as much as 100 atmospheres) is conceived as a network of canals in which submerged caissons or simple submarines move about carrying missiles together with all their erection and launch equipment. By what is now fairly conventional cost-effectiveness comparisons, missiles could be spaced with less than 2 kilometers between them. A number of areas in the world would lend themselves well to such a canal network scheme. The inclusion of periodic deeper sections or pools would allow preservation of the hardness provided by water cover even if the canals were broached and drained by cratering bursts. One version goes so far as to pump the water around canal loops so that the missile caissons could move unattended.

b. Problems

It is not a simple matter to design a sensing and control system for the unmanned caissons so that they can stay submerged, stay off the bottom, avoid running into the canal walls, and yet be rugged enough to withstand water, air, and ground shocks up to 100 atmospheres with the accompanying motions and accelerations. The water does provide adequate nuclear shielding, some protection from the airblast and debris impacts, and considerable improvement of

ground shock and EMP sensitivities. The water can also hide the missile caissons from hostile observers, but canals must be kept from forming ice so thick as to prevent movement or launch.

4. PERIODIC MOBILITY

a. Features

Since constant mobility is more than enough to make missile location uncertain, it is helpful to consider systems which move only part of the time. When parked, a missile carrier can be protected by a revetment or a garage and thus be much more survivable than a moving vehicle. Revetments can be constructed most inexpensively and can protect the vehicle to 2 or 3 atmospheres. Hard garages have been designed to shelter a truck up to 20 atmospheres. Such increased hardness cuts down the required deployment area as well as reducing the time spent in moving from shelter to shelter. The hardest and most compact scheme of this sort is one with deep pools spaced along canals, but this system does not lend itself to the concept of "dash-on-warning" in which the missile carrier runs for another shelter in less than the time between launch and impact of an enemy warhead.

b. Problems

It is difficult to keep the shelters austere and inexpensive, and thus cheap enough to make constructing large numbers practical. It is less than appealing to base missile survival on the dash-on-warning principal. It places an inordinate burden on rapid and unerring detection of enemy attack by aircraft, ICBM, IRBM, or sub-launched missile. Credibility of hardened garages at as high a level as 20 atmospheres peak overpressure is not easy to establish in the absence of atmospheric tests. In spite of such limitations the proposed concept of racing to a randomly selected shelter on warning could solve all the outstanding problems of either fixed or mobile missile basing concepts. It is

less sensitive to (1) high accuracy, (2) multiple warheads, (3) enemy intelligence, and (4) high operating costs and large area requirements for fully mobile systems.

5. UNDERWATER

a. Features

The creation and successful operation of submarine-based missile systems should not preclude consideration of other variations which operate on or under water. The present submarine systems operate in international waters and require deep water. Much of their expense and sophistication is bound up in their high mobility which requires a full submarine crew and power plant. In less hostile waters a slow-moving underwater barge or bottom-crawler, operated remotely or by a skeleton crew, could be allowed to park, drift, or anchor for most of the time.

b. Problems

Protection from enemy underwater operations must be provided such lethargic missile carriers, either by basing in sheltered waters (lakes, bays, lagoons, coastal waters) or by active surface or submarine patrols. While shallow water provides greater protection from water shock from underwater nuclear bursts, the wave action is shallow water could tumble a missile barge or drive it aground.

6. UNDERGROUND MOBILE

a. Features

The system that avoids the curse of zero CEP and yet offers least hazard of compromise by enemy surveillance while moving is a tunnel-based system. By running deep enough below ground, the effects on ecology and the public are minimized. The hardness of tunnels allows deployment areas to be smaller, thus minimizing the miles of tunnel required. Modern automation of tunneling promises relatively lower costs for a kilometer of tunnel than for a

kilometer of surface roadway in many circumstances. In almost all cases the few kilometers of tunnel necessary per missile should cost less than the many miles of roadway (with bridges, cuts, fills, surfacing, and upkeep) required for each softer missile carrier aboveground.

b. Problems

The biggest problem facing the tunnel-based missile is how to get out to launch. Portals, like fixed silos, are attractive targets for an enemy possessing highly accurate warheads. Many access and egress schemes have been considered, including underwater exits, multiple exits, exits not completed through the surface but ready to be blasted out when needed, etc. The least expensive and most likely to survive is the empty portal in rock with a blast door some hundred meters inside. Another problem for the tunnel systems is airblast propagating along the tunnels. For this, periodic blast doors are needed. A simple water-filled dip in the tunnel (water trap), through which the missile carriers crawl, has no moving parts and little added cost.

Tunnel integrity after attack by large yield nuclear burst may be a problem in areas of poor rock and particularly at intersections with major geologic faults or stratifications.

SECTION IV

CONCLUSIONS

Surviving the effects of nuclear explosions is a primary requirement for all modern strategic systems. If a weapon system cannot function in the hostile environment of wartime action, then how little it costs and how easily and reliably it operates are of little interest. Many missile or aircraft designs and many defense or communication concepts have been dropped for lack of credible survival under nuclear attack. Costly systems exist (e.g., Polaris), operationally inconvenient and unreliable systems are permitted to continue, but no strategic missile system long endures that shows vulnerabilities to nuclear effects. Demonstrable survivability is a necessary characteristic of any military system.

No hardness is sufficient to protect a single target from a determined enemy possessing nuclear weapons. At the other extreme, installations without protection must be so widely separated as to make impractical their joint or simultaneous use as alternate war headquarters. Multiple, hard, and separate targets offer the greatest protection possible for fixed basing schemes. For retaliatory strategic forces, survivability can be found via combinations of all these requirements: (a) hardness, (b) dispersion, and (c) numbers. When applied to a war headquarters, hardness is a straightforward and understandable asset. But it is not obvious how one "disperses" a war headquarters and it is even less obvious how one creates or operates large numbers of them. Something analogous to numerous widely spaced hard centers is possible through command and control systems which include redundancy and perhaps even deception to create a number of targets all equally likely to hold the commander.

Balanced hardness is made more difficult by the natural synergisms between protection measures. An installation buried so deep as to appear invulnerable to nuclear attack can force an enemy to explore more fully other means of attack, such as with chemical or biological weapons or with teams of sappers or saboteurs. Alternatively, he may find multiple nuclear attack on all redundant communications links more attractive than direct attack on the central headquarters itself.

The preceding review of war headquarters concepts and the sample list of missile basing schemes, each of which was at one time studied for its effectiveness in a nuclear environment, illustrates the diversity of answers possible to this single most important question of survival in a nuclear war. Each has elements of hardness and dispersion. Some rely on mobility or redundancy and others seek protection through deception to create false targets. All must find survival as likely under large-yield attack as from multiple small-yield attacks because weapon size, delivery accuracy, and target selection are largely open to enemy selection and beyond the control of the defenders. The concept of balanced hardness calls for fairly extensive study of all the likely options open to the attacker. Careful evaluation of present and likely future enemy weapon yields, delivery systems, and military objectives is a necessary adjunct or prelude to an estimate of the survival probabilities for the various protective postures that can be taken by the defenders. Costs involved in appropriate protective construction and the impact of added operational constraints can then be evaluated with such ensuing potentials in mind and some preferred overall balanced hardness designs selected consistent with the expected threats.

However, experience suggests that those protective schemes which show the greatest promise of assured survival may be selected over systems of seemingly greater cost-effectiveness but less certain survival. When there is considerable uncertainty about the influence of a particular weapon effect on some

portion of a protected facility, survivability and cost-effective estimates for that installation may lack the credibility and assurance necessary to proceed from concept stage to design or construction phase. In fact, the system may never come into being at all because of that lack of precise knowledge of some weapon effect. Some dead or dying examples of this malaise lie among the basing schemes reviewed here.

Careful selection of spacing, blast hardness, and nuclear shielding allows one to achieve protection that is equally good under attacks by many small warheads or by one or a few large-yield weapons. It is wise, however, to consider as a part of the balanced design protection against attacks with conventional explosive weapons with chemical or biological agents or with special ground troops. Even then, each added measure of protection forces an enemy attack planner to seek or invent other mechanisms of destruction more likely to succeed than those against which the protection was designed.

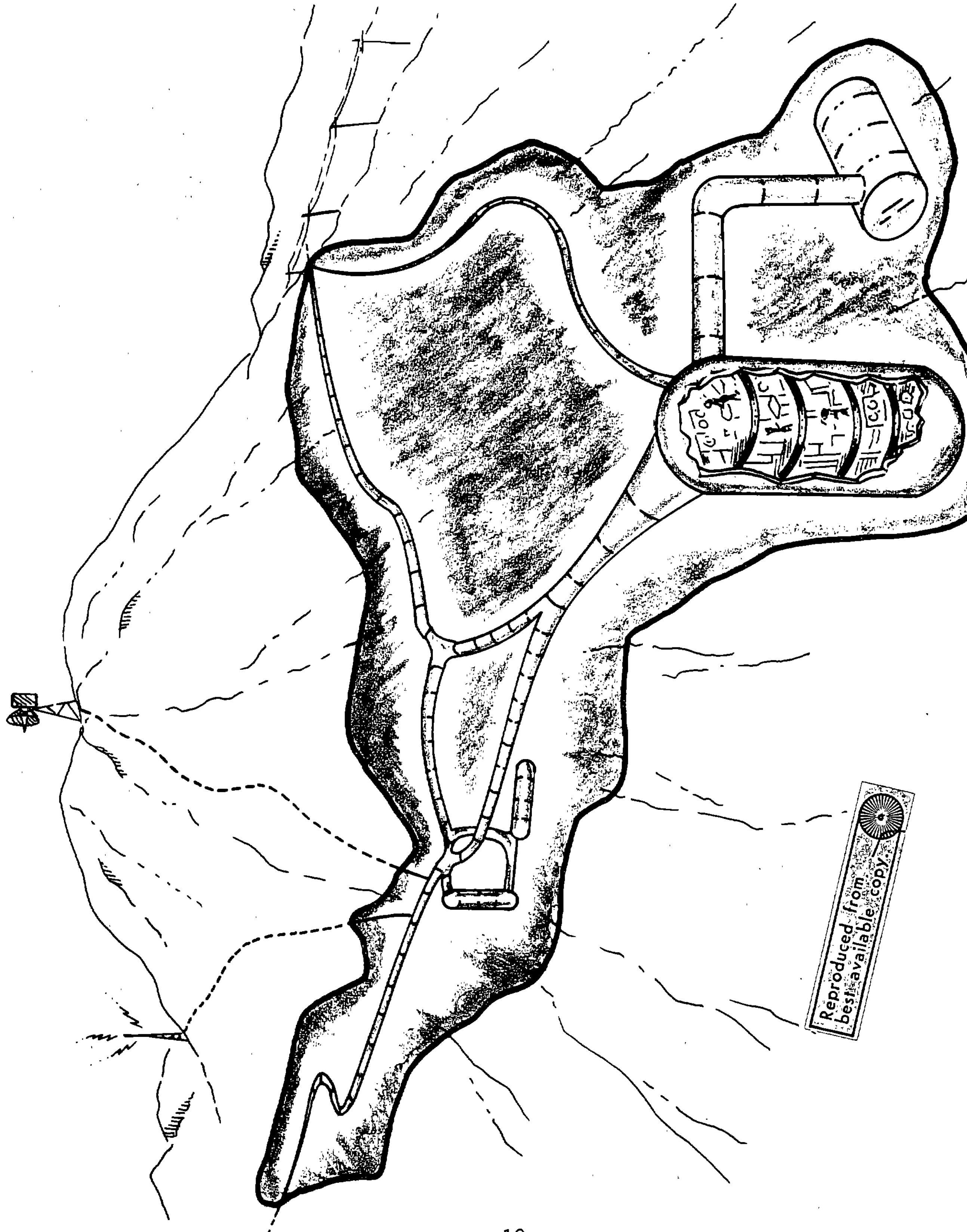

FIGURE 1. UNDERGROUND COMMAND CENTERS

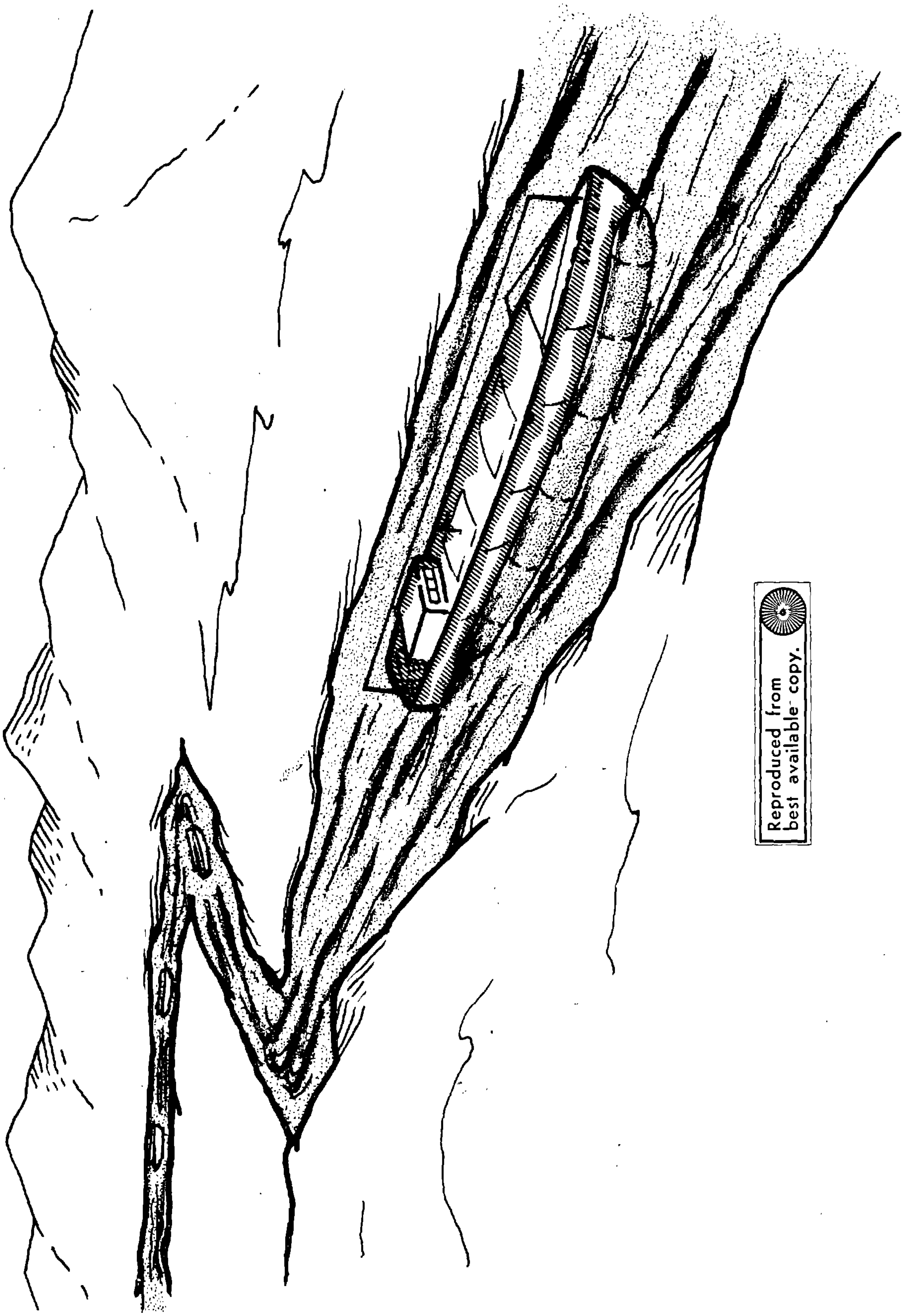

FIGURE 2. BARGE-BASED HEADQUARTERS

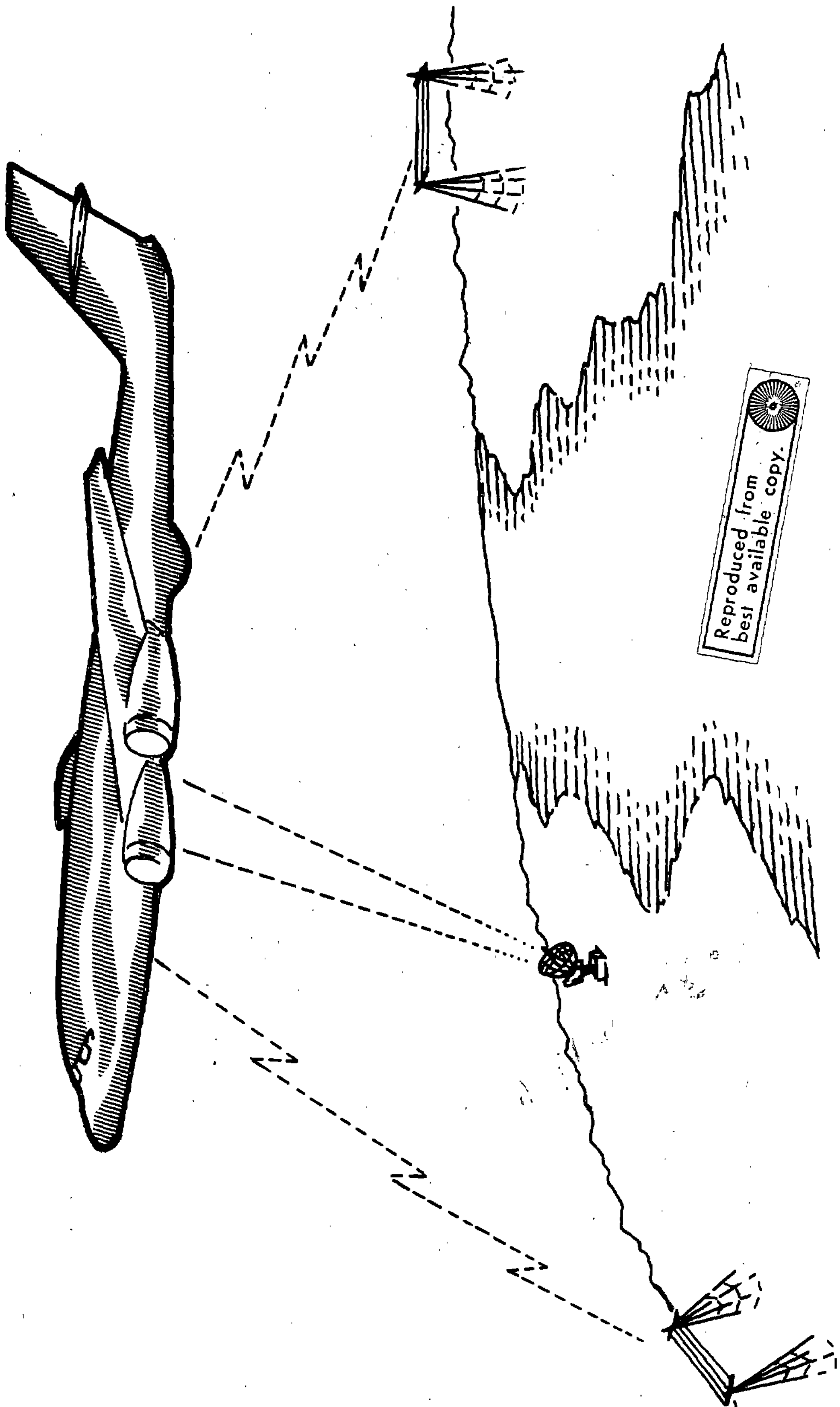

FIGURE 3. AIRBORNE COMMAND POST

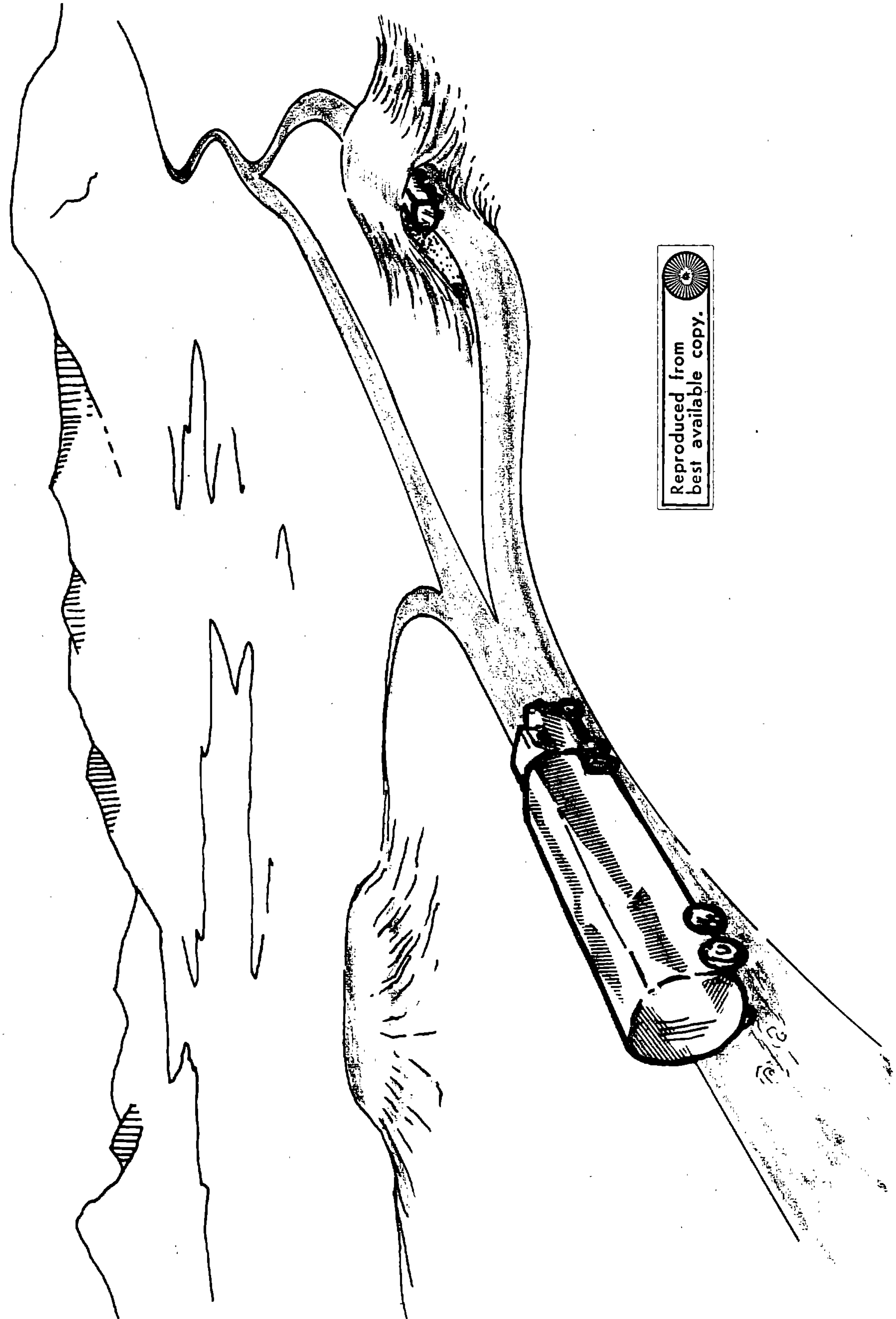

Figure 4. Road Mobile with Revetments

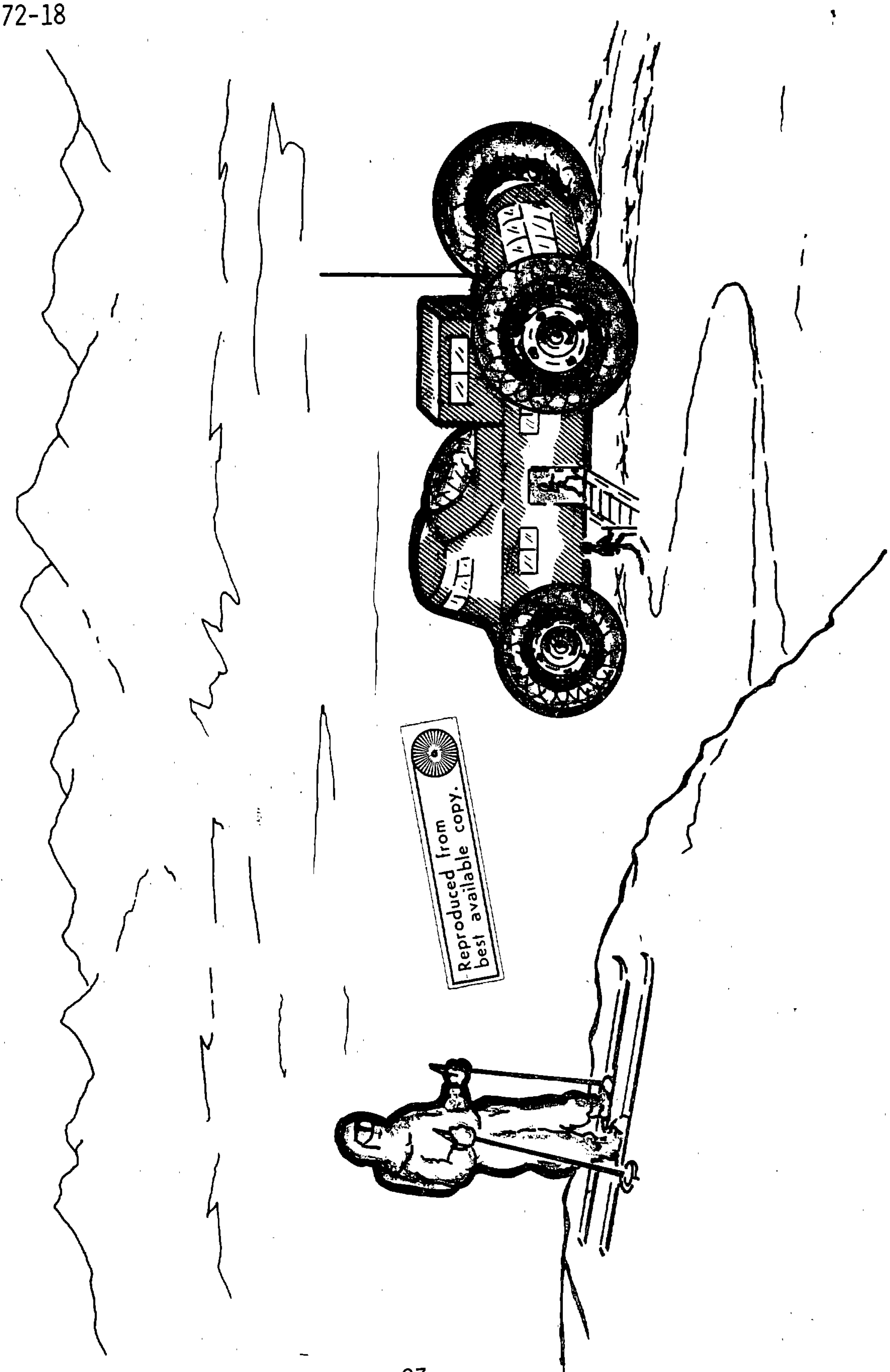

FIGURE 5. OFF-ROAD MOBILE CENTER

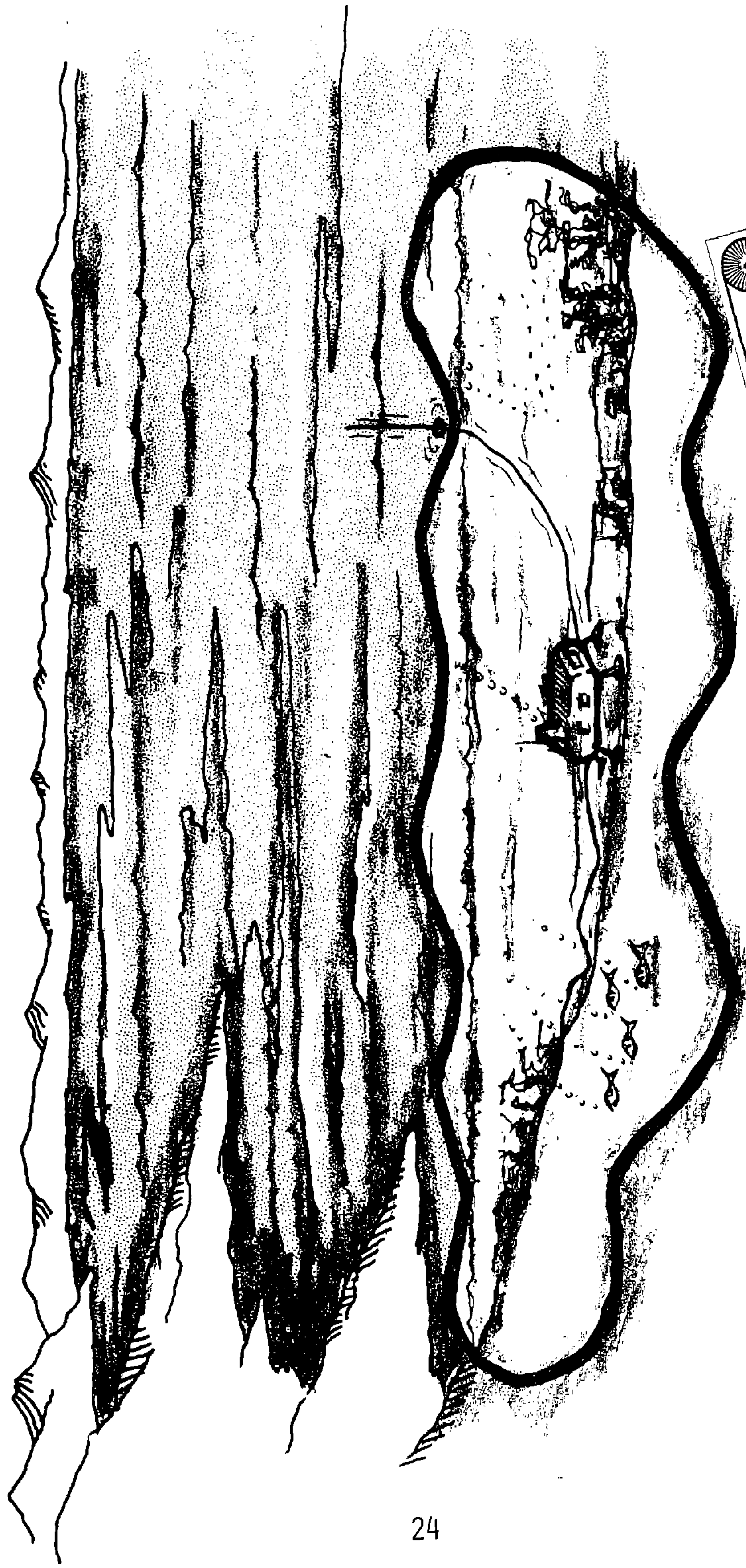

FIGURE 6. SHALLOW-WATER MOBILE CENTER

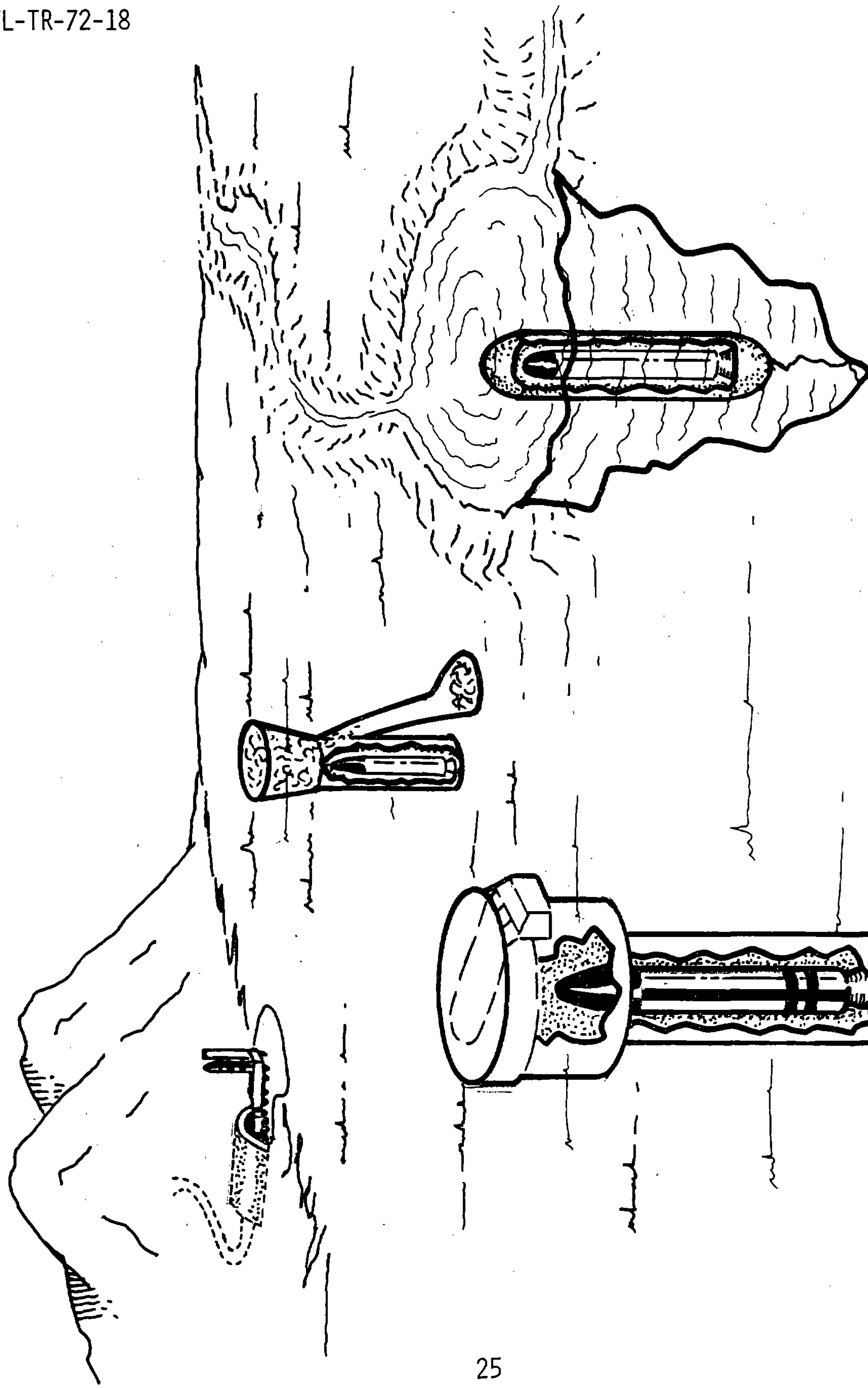

Figure 7. Fixed Launch Point Missile Basing Concepts

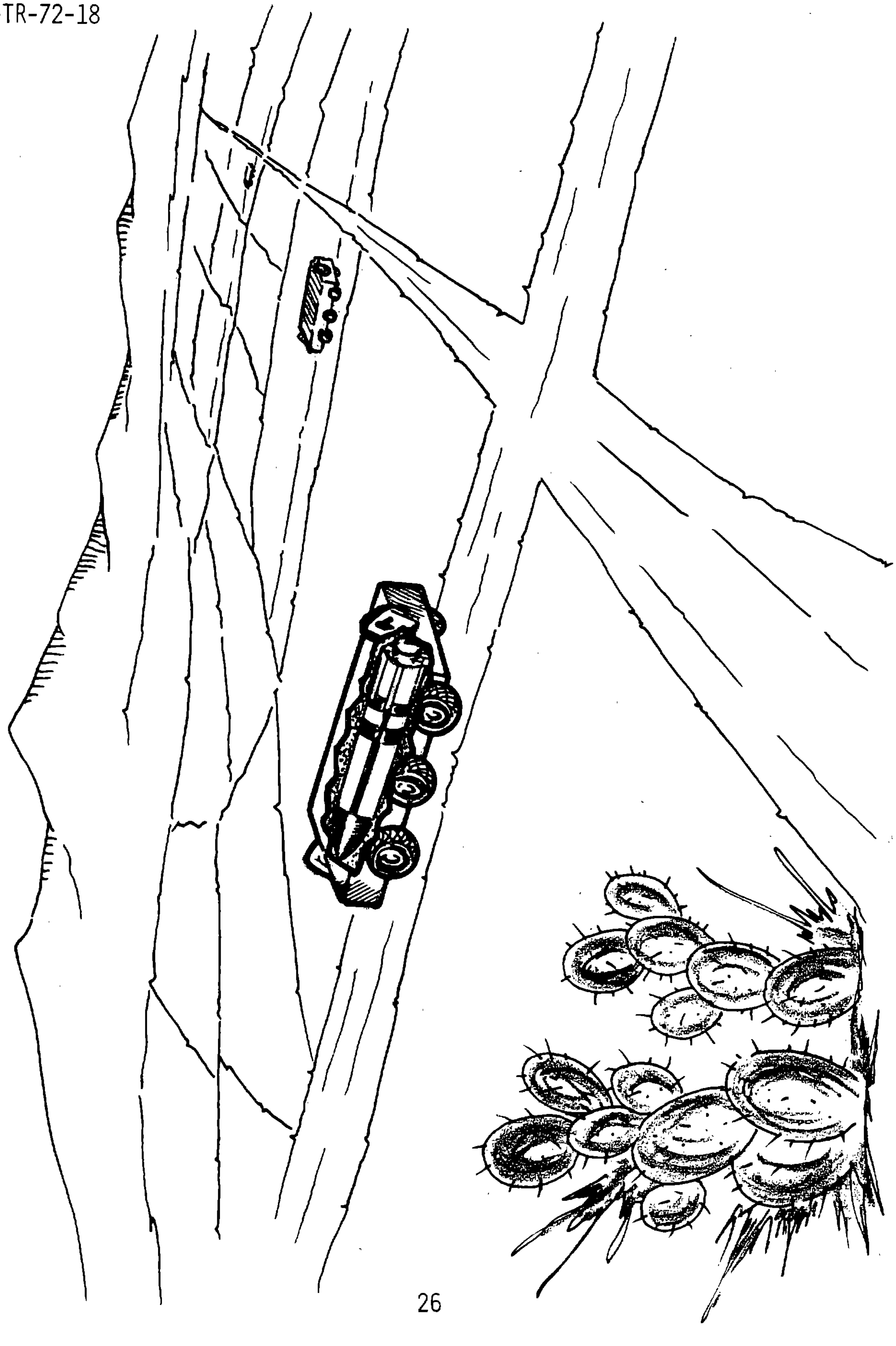

Figure 8. Land-Mobile Missile Launchers

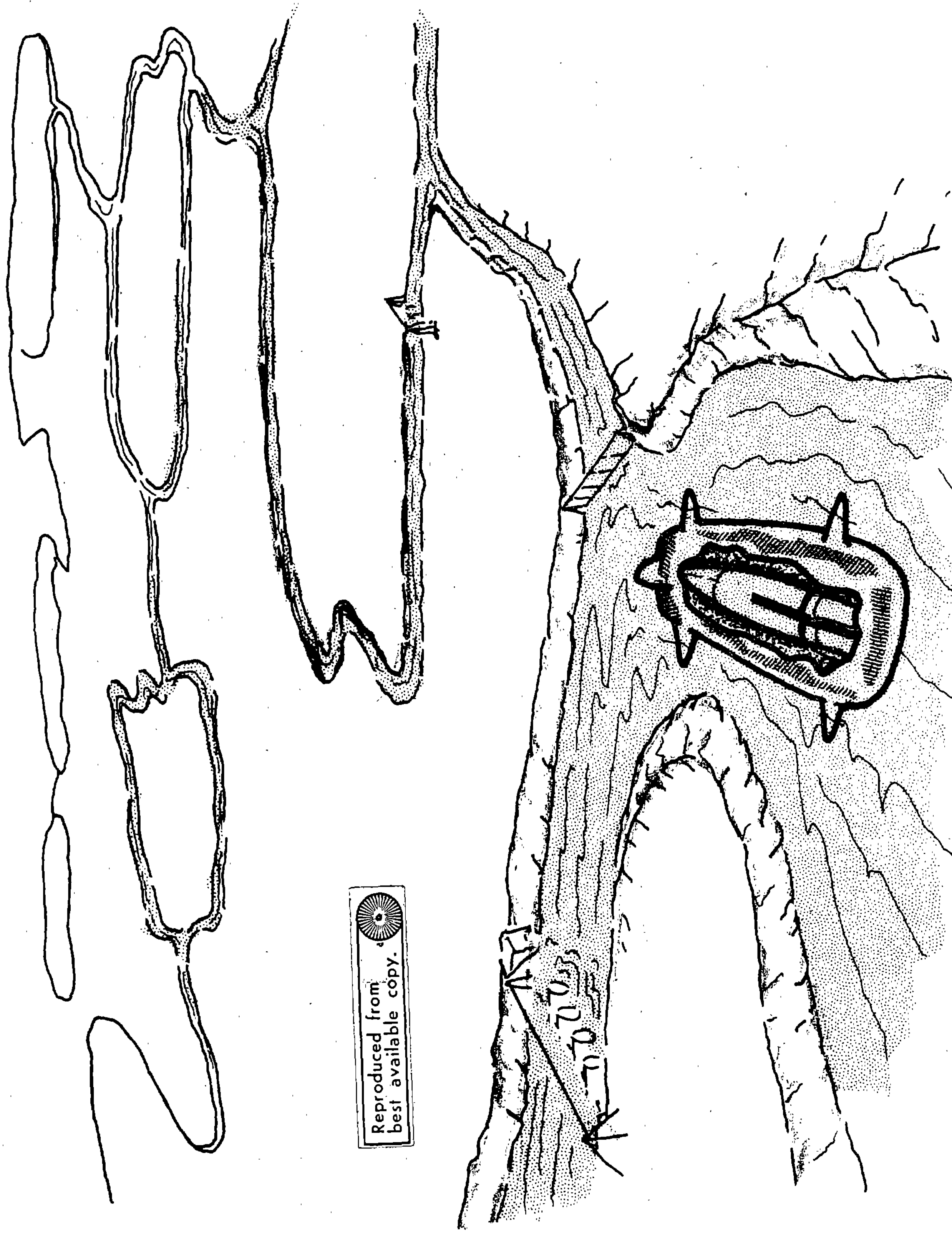

FIGURE 9. CANAL MOBILE MISSILE LAUNCHER

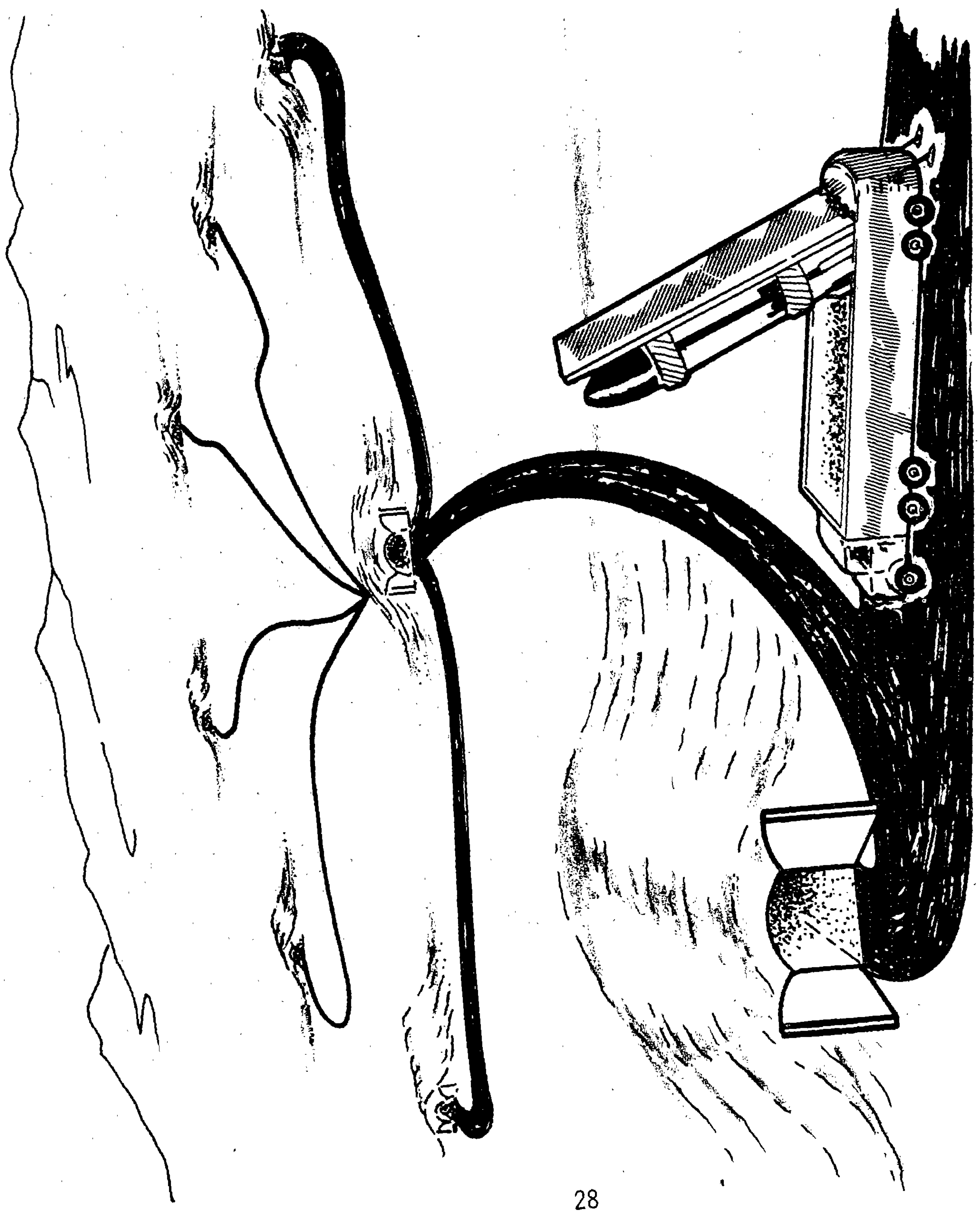

FIGURE 10. HARD GARAGE AND DASH-ON-WARNING

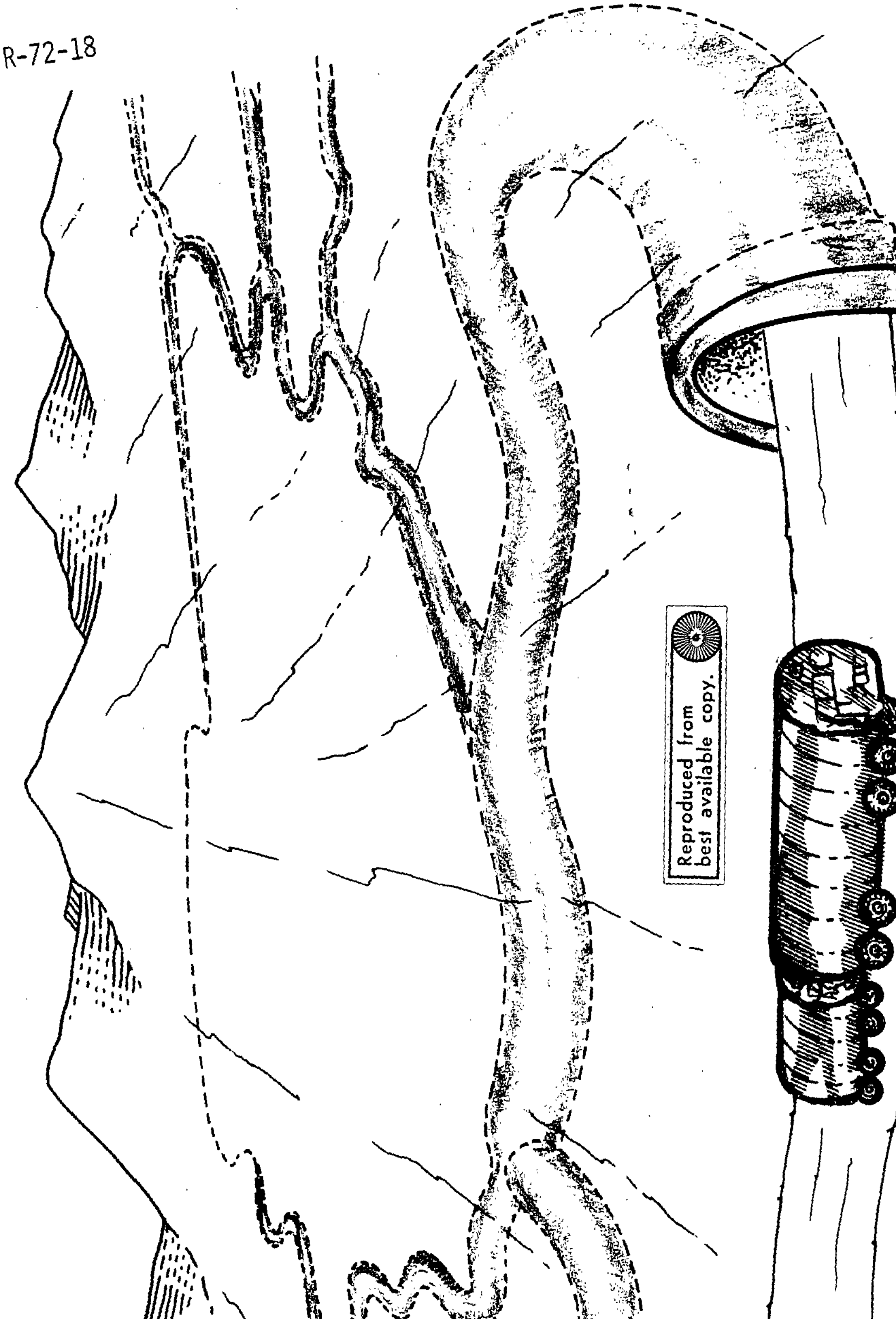

FIGURE 11. UNDERGROUND MOBILE LAUNCHER